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FECUNDITY, SIZE AND DISPERSAL OF THE WHITE WAX SCALE, *CEROPLASTES DESTRUCTOR* NEWSTEAD (HEMIPTERA: COCCIDAE), IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA.

ABSTRACT

FECUNDITY, SIZE AND DISPERSAL OF THE WHITE WAX SCALE, *CEROPLASTES DESTRUCTOR* NEWSTEAD (HEMIPTERA: COCCIDAE) IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA.

Ceroplastes destructor Newstead has recently attained pest status in areas of South Africa where citrus is grown, particularly on *Citrus reticulata* in the Western Cape Province. The fecundity, fertility and dispersal of *C. destructor* were studied as part of a comprehensive overview of its morphology, biology and population dynamics, with the aim of providing a more informed basis for control programs. Fecundity varied significantly both between orchards ($P<0.01$) and between individual females from the same orchard ($P<0.001$). Female body-size also differed between orchards ($P<0.05$) and was positively correlated with fecundity ($r^2=0.84$). The oviposition period was longer for large individuals. No differences in fertility were found between orchards ($P>0.05$). Dispersal was by 1st-instar nymphs, mainly on air-currents, and the numbers caught on a series of sticky traps up to 4m from the source were very similar, suggesting that wind dispersal was very efficient. The numbers caught appeared to be positively correlated to the initial population. The population of 2nd-instar nymphs on the seedlings after 6 weeks was smaller after an initially heavy infestation than on those initially more lightly infested.

Key words: hosts, incubation period, *Psidium quajava*, *Ponocirus trifoliata*, *Eugenia malaccensis*, *Gardenia thunbergia*.

INTRODUCTION

The white wax scale, *Ceroplastes destructor* Newstead (Homoptera: Coccidae), is among the complex of insects for which citrus is a suitable host. It is increasing both in numbers and distribution in citrus growing areas of the western Cape Province, South Africa, and is widely distributed in Sub-Saharan Africa from where it is thought to have originated (De Lotto, 1965; Snowball, 1969). It is a polyphagous species that infests various trees, shrubs, and ornamentals. Ben-Dov (1993) recorded it off 22 plant families, while Snowball (1969) and Qin & Gullan (1994) considered that it was found on almost all citrus cultivars. In South Africa, it has been recorded from *Citrus* spp., *Psidium guajava* and *Ponocirus trifoliata* (De Lotto, 1965). In addition, in the Western Cape Province, we have recorded it from easy-peel citrus, *Citrus reticulata*, on which it is now a significant pest, and off *Eugenia malaccensis* and *Gardenia thunbergia*.

The fecundity of *C. destructor* has been determined on citrus in Australia by Zeck (1934), Smith (1970) and Beattie (1988), and in New Zealand by Lo (1995) but no information is available for South Africa.

Greathead (1997) has recently reviewed the dispersal of scale insects and considered that spread on wind currents was the major means of dispersal both within and between host plants over a considerable distance (see also Washburn & Frankie, 1981; 1985; Washburn & Washburn, 1984; Yardeni, 1987). The effect of crawler density on the number and distance of dispersion has, however, not been much studied. Our observations in the field revealed that crawlers moved considerable distances between trees. On several occasions, we have noticed that citrus trees that had been free of scale during one generation had become heavily infested in the next. These trees were up to 4m away from any infested trees. This colonization is presumed to be due to crawlers being carried on wind currents since the role of humans and animals in dispersing crawlers in established orchards is thought to be minimal. Experiments were therefore designed to assess whether crawlers could be dispersed on air currents up to 4m and how initial crawler density affected the rate of emigration.

In this paper, our observations on the fecundity, fertility and crawler dispersal of the *C. destructor* will be discussed.

MATERIALS AND METHODS

Fecundity and size: the fecundity of *C. destructor* was assessed using the following procedures:

Daily oviposition by individual females. Gravid females were collected from twigs with both isolated and overcrowded populations of adult females in approximately equal proportions. Each female was overturned and observed under the microscope for the presence of eggs beneath its ‘brood chamber’. Only females that had not yet started egg laying were used; these are recognisable because the venter of the abdomen contracts on gravid females and a mass of white, powdery wax is secreted around the vulva. Each female was stuck upside-down in the centre of a numbered glass slide using gum arabic (Bedford, 1968). The slides were placed in shallow glass-topped boxes with some wet cotton wool to raise the humidity. Paper trays (5.0x3.8cm) were inserted into the boxes underneath each glass slide. Each female was suspended on the slide with the ‘brood chamber’ facing downwards so that, as the eggs were laid, they fell onto the paper tray. Both the slide and paper tray were given the same number. The boxes were kept in an incubator at 27°C and 60±5% RH, and were checked every day at 16:00h. A total of 88 females of varying body-size off *C. reticulata* and 44 females off *E. malaccensis* oviposited successfully.

Once oviposition had started, the slides were collected and tapped gently to dislodge the eggs from the 'brood chamber'. All the eggs that dropped onto the paper trays beneath were transferred onto moist filter paper and counted. The slides were put back into the boxes and the assessment continued until no further eggs were laid. This provided information on the oviposition periods of each individual female collected from each of the four farms and on any correlation between female body-size and fecundity.

Female body-size (length and width) was measured under a micrometer eyepiece after the body wax had been removed (see Wakgari and Giliomee (1998) for details).

Fertility: egg viability and crawler emergence were investigated by placing a specified numbers of eggs of known age in 10x5cm vials with a cotton wool stopper. The vials were laid horizontally in an incubator at 27°C and 60±5% RH, with the stopper facing a light source (emerging crawlers are positively phototropic). The eggs were observed daily to determine whether they had hatched and whether viable crawlers had emerged. Once egg hatch or crawler emergence was noted, the contents of the vials were emptied onto dry filter paper and the number of crawlers counted. This procedure was repeated until no further hatching was observed (thus giving the incubation period). The number of infertile eggs was also recorded.

Dispersal: for this experiment, 16 easy-peal citrus seedlings less than 1 year old, about 1.2m tall and each planted in a 20 litre pot, were infested with four densities of *C. destructor* crawlers (i.e. 400, 600, 800, 1000; i.e. 4 replicates of four densities), each crawler being transferred separately with a camel-hair brush. The seedlings were placed 10 metres apart on a level field. Around each seedling was placed 16 sticky-traps (each 10cm wide and 30cm tall), one at 1, 2, 3 and 4m distances along four compass points (N. S, E and W) away from the source plant; there were therefore 16 treatments. Each trap was tied to a stake 1m above the ground. The traps were collected after six weeks (the maximum duration of the first instar) and the number of crawlers caught counted.

Data analysis: differences in female fecundity and fertility between orchards and between females of different body sizes were analyzed using one-way ANOVA. The relationship between female body size and fecundity was analyzed using correlation analysis. Factorial ANOVA was used to determine the effect of crawler density at the source on the observed number of crawlers caught. The observed number of crawlers caught at each distance was multiplied by its respective proportional increase in radius to account for the reduction in circumference taken up by the traps as distance increased and to make comparison possible. The effect of compass directions on the number of crawlers captured was computed using both full and reduced models of dummy variables.

RESULTS AND DISCUSSION

Fecundity and size

Total egg production per ovipositing female of *C. destructor* varied significantly between orchards ($P<0.01$). Females collected off *Citrus reticulata* produced significantly more eggs than those off *E. malaccensis* (Table 1). Individual females from the same orchard and off different hosts also varied in their fecundity, ranging from 37-6355/female off *C. reticulata* and 13-4514/female off *E. malaccensis*. The variation between citrus orchards and between *C. reticulata* and *E. malaccensis* may be due to differences in the availability of soluble nitrogen as this is known to have great impact on the survival, fecundity and size of sap-sucking insects (McClure, 1980). Although not tested in the present study, the size of *C. destructor* is known to be positively correlated with the nitrogen levels of citrus trees (Beattie *et al.*, 1990). The variation in female fecundity between orchards has implications for the size of the succeeding scale populations and hence in the forecast of possible outbreaks.

The range in fecundity for *C. destructor* reported here is similar to that found by Lo (1995: 12-5214) infesting citrus in New Zealand. However, the maximum number of eggs laid by individual females of *C. destructor* collected off citrus (6355) exceeded previously reported maxima of 3000 (Smith, 1970), 5475 (Beattie, 1988) and 5214 (Lo, 1995). The mean fecundity for the *C. destructor* in the present study (1774) was less than the 3000 reported by Zeck (1934) but slightly greater than the 1750 reported by Olson *et al.* (1993) and 1233 given by Lo (1995).

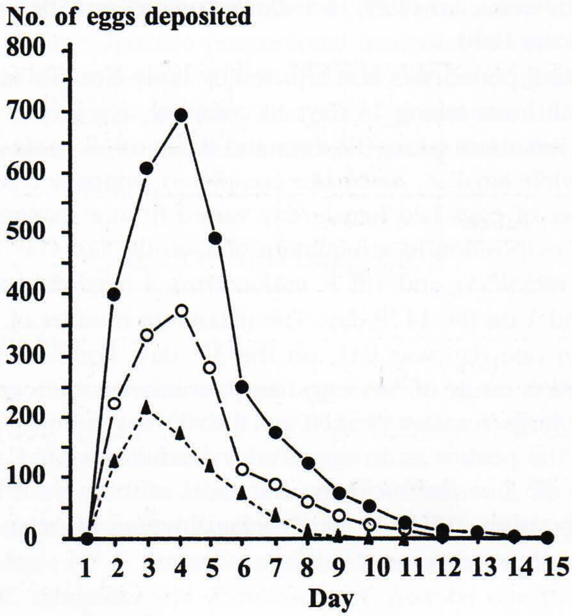
The size of *C. destructor* varied significantly between orchards ($F=7$; $P<0.001$) and between *C. reticulata* and *E. malaccensis* ($F=2.65$; $P<0.05$). Length and width were positively correlated off both hosts (*C. reticulata* ($r^2=0.89$); *E. malaccensis* ($r^2=0.79$)). Size and fecundity were also positively correlated (*C. reticulata* ($r^2=0.84$); *E. malaccensis* ($r^2=0.77$) (Table 2)). These results are similar to those of Yardeni & Rosen (1995, for *Ceroplastes* *floridensis* Comstock), Lo (1995, for *C. destructor*) and Bedford (1968, for *Ceroplastes sinoiae* Hall).

The oviposition period was also affected by body-size (Table 2), with large females off both hosts taking 14 days to complete egg laying; medium-sized females off *C. reticulata* taking 12 days and those off *E. malaccensis* 11 days (Figs 1 & 2), while small *C. destructor* completed oviposition in 10 days. The average number of eggs laid/female/day varied from a maximum of 701 on the 3^{rd} day of oviposition to a minimum of 1 on the last (14^{th}) day for large females off *C. reticulata*; and, off *E. malaccensis*, a maximum of 537 eggs on the 2^{nd} day and 1 on the 14^{th} day. The maximum number of eggs laid by a large female in one day was 941, on the 3^{rd} day. For *C. sinoiae*, Bedford (1968) recorded a mean of 545 eggs and a minimum of 1 egg/female/day. Egg laying by large females peaked on the 4^{th} day whereas, for medium-sized females, the peak was on the 4^{th} day for females off *C. reticulata* but on the 3^{rd} day off *E. malaccensis*. Small females off both hosts laid their peak number of eggs on the 3^{rd} day. The average duration of oviposition off both hosts for all size categories was 11 days.

Table 1. Mean fecundity, fertility and body-size of adult female *C. destructor* infesting *Citrus reticulata* and *Eugenia malaccensis* at four farms in Western Cape Province, South Africa.

Farm[3]	Fecundity (n*)	Fertility[2] (n**)	Days to hatching (range)	Body size[1] (mm±SE)		
				Length	Width	n*
WEF	1935 (74)	97.8 (1100)	16-17	4.20 (0.38)	2.52 (0.10)	133
RFF	1720 (84)	97.6 (5055)	16-19	4.33 (0.13)	2.52 (0.08)	110
RUS	1838 (74)	96.1 (2550)	16-19	4.16 (0.11)	2.50 (0.08)	80
STL	1602 (74)	98.6 (2660)	16-17	4.50 (0.10)	2.63 (0.07)	80
Mean	1774 (77)	97.5 (2841)	17	4.30 (0.18)	2.54 (0.08)	96
ANOVA	0.05	NS	NS	0.05	0.05	

1: Dewaxed adult female; 2: % crawler emergence for eggs incubated at 27°C and 60% RH; 3: Farms: WEF = Welgevallen Experimental Farm (host = *C. reticulata*); RFF = Rhodes Fruits Farm (host = *C. reticulata*); RUS = Rustenburg Estate (host = *C. reticulata*) and STL = Stellenbosch (host = *E. malaccensis*); n* = sample size; n** = no. of eggs incubated; SE = Standard Error of Mean; ANOVA = P<0.05 significant differences between farms; NS = not significant (*P*>0.05).



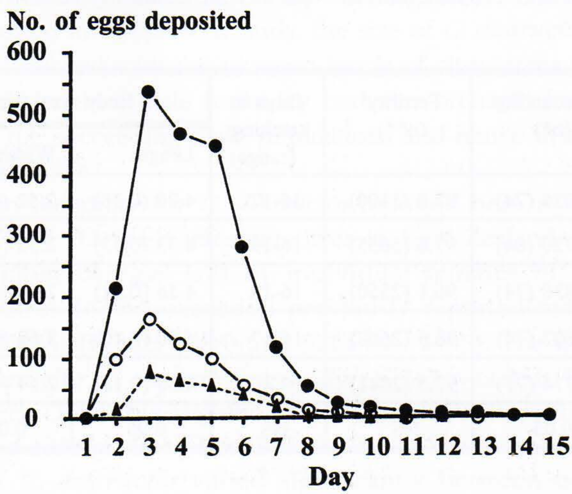


Fig. 1. Effect of body size on duration of oviposition by females of *Ceroplastes destructor* infesting *Citrus reticulata*. Where —•— = large, -o- = medium and --▲-- = small body size.

Fig. 2. Effect of body size on duration of oviposition by females of *Ceroplastes destructor* infesting *Eugenia malaccensis*. Where —•— = large, -o- = medium and --▲-- = small body size.

Table 2. Effect of host-plant species and body-size on the fecundity for *C. destructor*.

Host	Size	Length (range mm)	No. females	Mean no. eggs/♀	Oviposition period (days)
Citrus	Small	3.70-4.15	32	574	10
	Medium	4.16-4.61	30	1304	12
	Large	4.62-5.41	26	1970	14
Eugenia	Small	2.20-3.33	12	303	10
	Medium	3.34-4.47	12	567	11
	Large	4.48-5.60	20	2176	14

The incubation period ranged from 16 to 19 days (mean 17 days), which was shorter than the 25-31 days reported by Cilliers (1967) for *Ceroplastes mimosae* Sign. in South Africa. In field populations with *C. destructor* in the present experiments, eggs laid by the same generation of females hatched over a period of up to two months. After hatching, the crawlers remained within the 'brood chamber' for about two days before moving onto the leaves or young twigs.

DISPERSAL

Wind has been shown to be the principal dispersal agent for the crawlers of scale insects (Jenkins *et al.*, 1953; Hulley, 1962; Washburn & Frankie, 1985; Yardeni, 1987; Greathead, 1997). Previous work on the wind dispersal of *C. destructor* (Hely, 1960) showed they could be carried at least 6m. Distances recorded for other scale insects are: 135m for the black scale (*Saissetia oleae* (Bernard) (Quayle, 1916); 54m for the soft brown scale, *Coccus hesperidum* L. (Hoelscher, 1967) and 3.5km for *Icerya seychellarum* (Westwood) trapped at 6m above surrounding vegetation (Hill, 1980). Dispersion distance has also been shown to be affected by the height of take-off and wind speed (Greathead, 1972; Wainhouse, 1980; Moran *et al.*, 1982) and by the temperature and humidity of the environment (Greathead, 1972).

Table 3 shows the mean number of crawlers caught per trap at each distance and there appears to be a significant reduction in the number caught on the traps further from the source. However, because the four traps at each distance were all the same size, the proportion of the circumference of the circle that each trap covered got smaller the further the traps were from the

Table 3. Mean number of crawlers captured per trap after 6 weeks at four distances from citrus seedlings infested with four densities of *C. destructor* crawlers; trap size = 30x10cm; trap distance from the ground = 1m. Also the mean number of 2nd-instar nymphs remaining on each seedling at the original site of release and the number elsewhere on the plant, six weeks after release.

Crawler density	Distance from seedling (m)				Mean ± SE	No. on seedling after dispersal (% of original density)	No. settled on nearby branches
	1	2	3	4			
400	8	9	5	2	6 (1.6)	31 (7.8)	2
600	19	11	12	4	11.5 (3.1)	34 (5.6)	2
800	18	16	21	7	15.5 (3.0)	9 (1.1)	2
1000	29	18	16	7	17.5 (4.5)	8 (0.8)	0
Mean	18.5	13.5	13.5	5			

Table 4. As for table 3 but with the actual number of crawlers caught multiplied by a factor to make the size of the traps proportional to the circumference at each distance: i.e. x1 at 1 m, x2 at 2 m, x3 at 3 m and x4 at 4 m.

Crawler density	Distance from seedling (m)				Mean ± SE
	1	2	3	4	
400	8	18	15	8	12.3 (2.5)
600	19	22	36	16	23.3 (4.4)
800	18	32	63	28	35.3 (9.7)
1000	29	36	48	28	35.3 (4.6)
Mean	18.5	27	40.5	20	

seedling. This is taken into account in Table 4, which shows the mean number of crawlers caught on each trap multiplied by a factor which equalises the proportion of each circumference covered by the four traps. The resultant figures represents traps about 1/16th of each circumference. It is clear that, when compared on this basis, the number of crawlers being caught does not appear to fall off significantly with distance (up to 4m) as there are approximately the same number being caught at 4m as at 1m (although the numbers at the intermediate distance do seem to be greater). It is also clear that the number caught was greater on those traps associated with seedlings with initially higher crawler densities ($F=7.7$, $P=0.001$). At what distance a clear reduction in the number caught would be recorded is unclear but, since take-off height in the field would usually be greater than the 1m in this study, the distance that *C. destructor* crawlers could be dispersed on wind currents in the field could be much greater than found here.

Table 3 also shows the number of 2^{nd}-instar nymphs which were still present on the seedlings six weeks after release and it clearly shows that more remained on the seedlings with an original crawler density of 400 and 600 than on those with 800 and 1000, suggesting that there may have been some crowding effect on dispersal.

The effects of direction were tested using dummy variables. The reduced model differed from the full model for the observed density ($F9, 253 = 2.09$; $P=0.03$). However, none of the coefficients for the dummy variables were significant ($P>0.05$) for both observed and expected density. Therefore, a common intercept and common slopes for both distance and density were assigned to the four compass directions. The reduced model did not differ from the full model for the expected density ($F9, 253 = 1.26$, $P=0.26$) indicating that common regression coefficients could be assumed for all four compass directions. Therefore, it can be said that direction on its own had no significant effect on the number of crawlers caught and that the wind was blowing from all four directions at sometime during crawler dispersal.

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